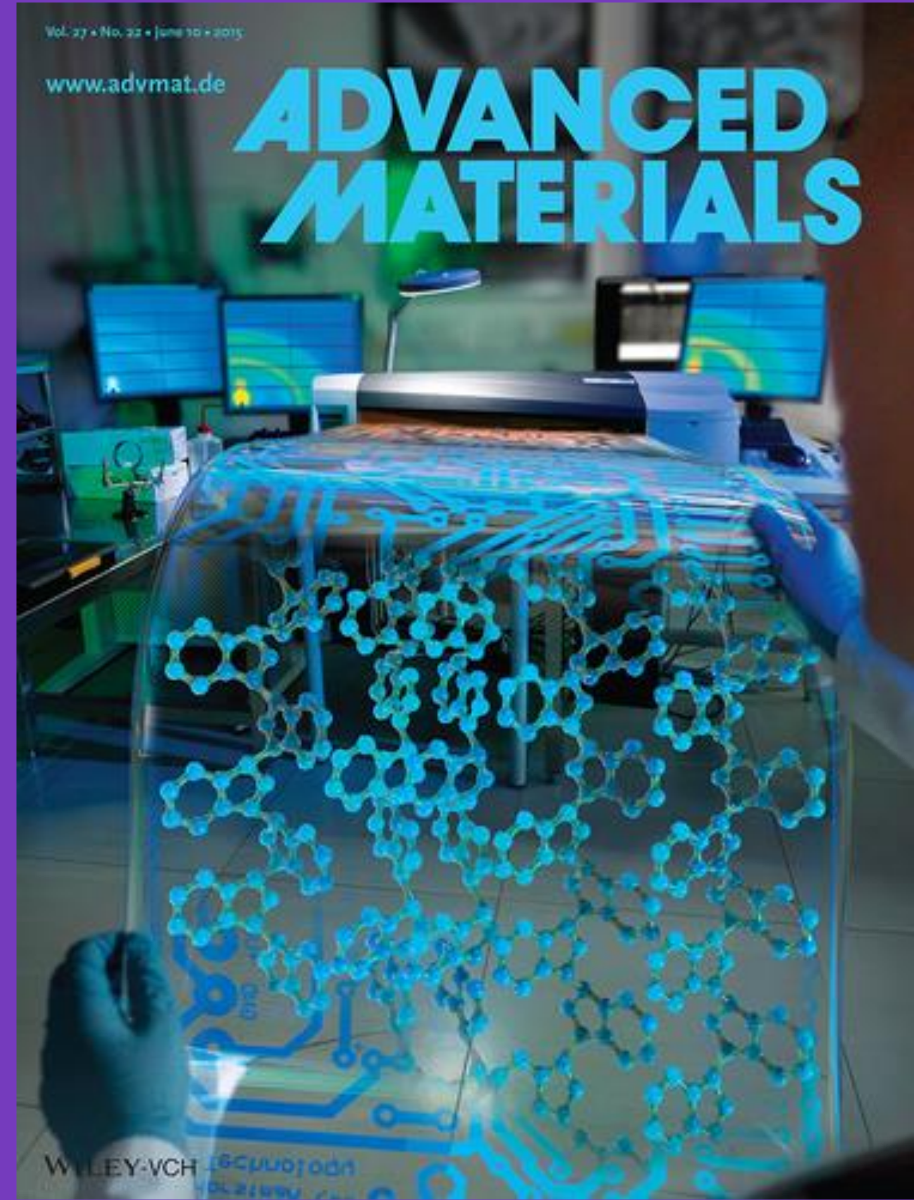
ELEC-E9210 Organic Electronics: Materials, Devices & Applications

Characterization of Organic Materials

Aalto University
School of Electrical
Engineering

https://organicelectronics.aalto.fi



From Last Class

Previously….

- ***Electronic properties*** and ***different transport mechanisms*** in OSC (doping, trapping effect, field-effect transport)
- ***Optical excitation*** in OSC (optical transitions, light emission mechanism, excitons, etc.)

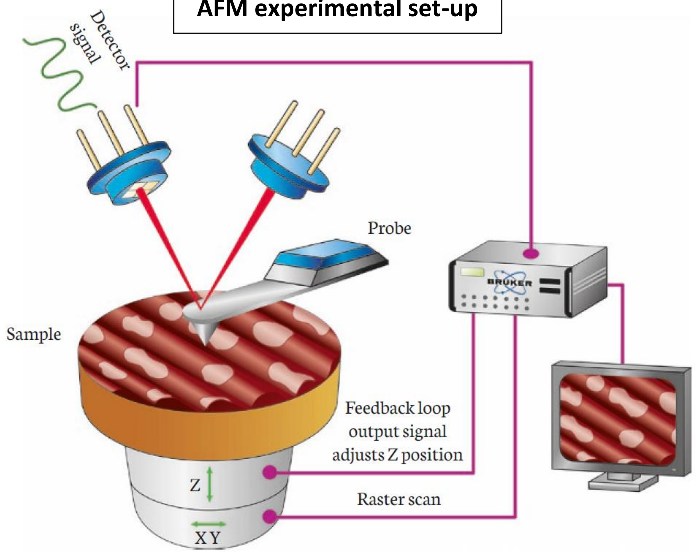
Today´s Class

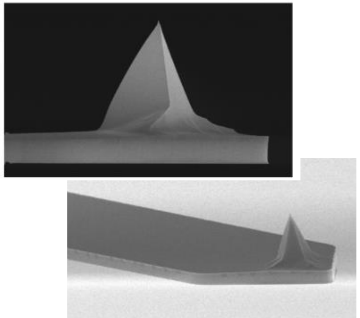
- **Characterization** of organic materials

Atomic Force Microscopy (AFM)

Atomic force microscopy helps study the surface properties of materials, based on the ***interaction between surface itself and the AFM tip***

AFM experimental set-up





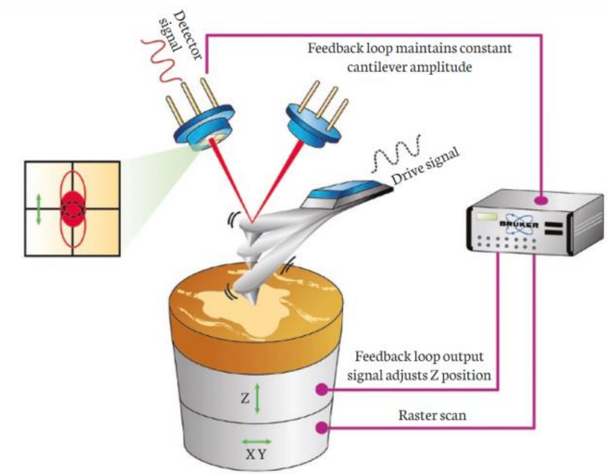
Pt-Ir tip

Have a look here
(from YouTube, ParkSystems)

materials available @Bruker.com

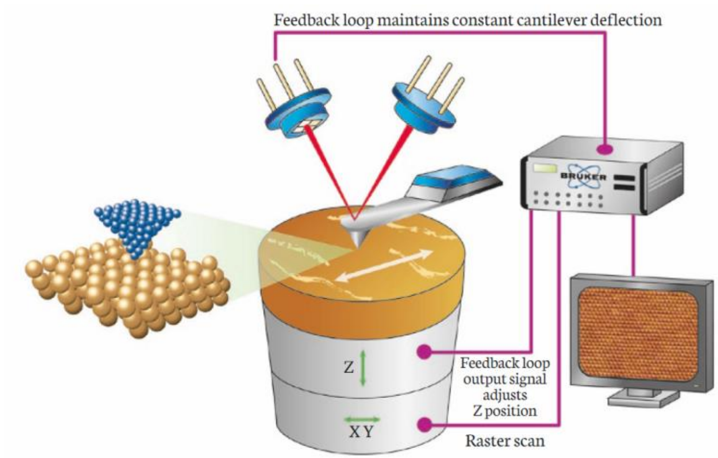
Atomic Force Microscopy (AFM): Scanning Modes

non-contact mode (NC-M)



cantilever is set to vibrate at its resonance frequency. When tip is brought close to sample surface, the forces between the tip and the surface affect its resonance frequency

contact mode (C-M)

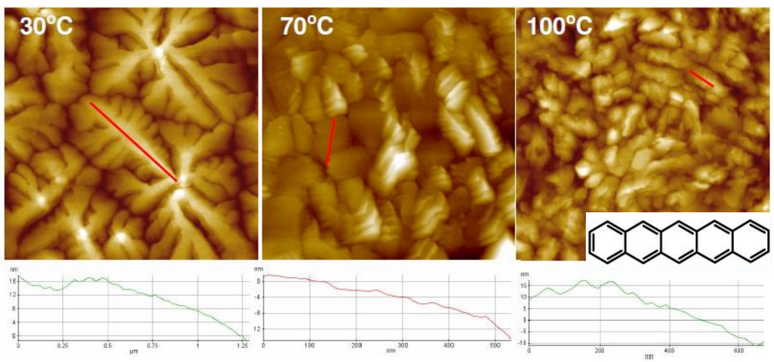


probe is in ***permanent physical contact*** with the sample surface as it scans, with changes in topography causing the cantilever to bend up and down

AFM (Surface) Characterization of OSC

AFM is fundamental in studying OSC morphology in relation to ***process parameters***, ***substrate surface***, ***thickness*** and ***molecular arrangement***

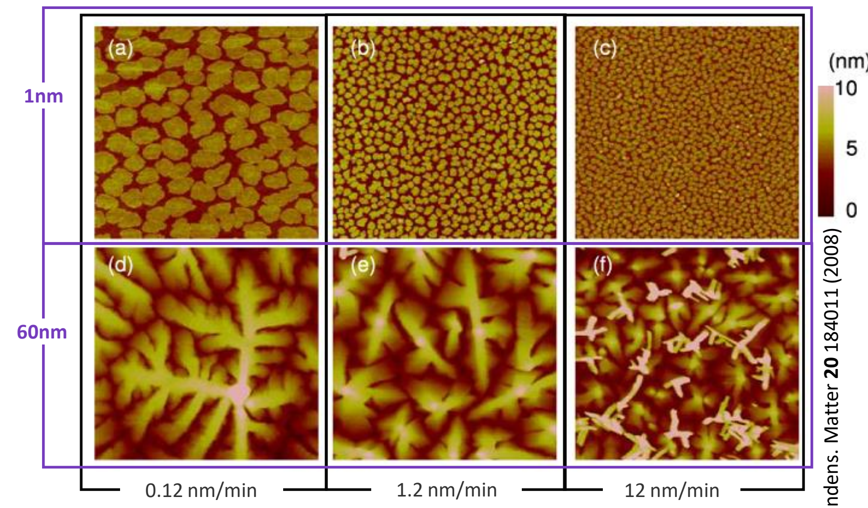
substrate temperature



AFM images of 100nm pentacene deposited on SiO_2 at different temperatures (deposition rate 0.2Å/s, scan size 5μm × 5μm).

https://shodhganga.inflibnet.ac.in/bitstream/10603/120058/8/08_chapter%203.pdf

rate & thickness



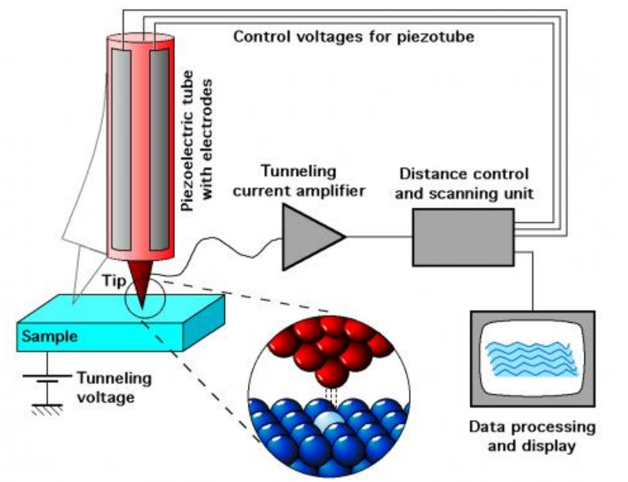
AFM images of pentacene deposited on SiO_2 (scan size 5μm × 5μm)

J. Phys.: Condens. Matter **20** 184011 (2008)

Scanning Tunneling Microscopy (STM)

Scanning Tunneling Microscopy helps study the surface properties of materials with high resolution and it is based on the ***charge tunneling between surface itself and the AFM tip***

STM experimental set-up



sharp tip approaches a ***conducting surface*** at a very close distance (1nm) → tunneling current starts to flow. The tip is mounted on a piezoelectric tube, which allows tiny movements by applying a bias to its electrodes.

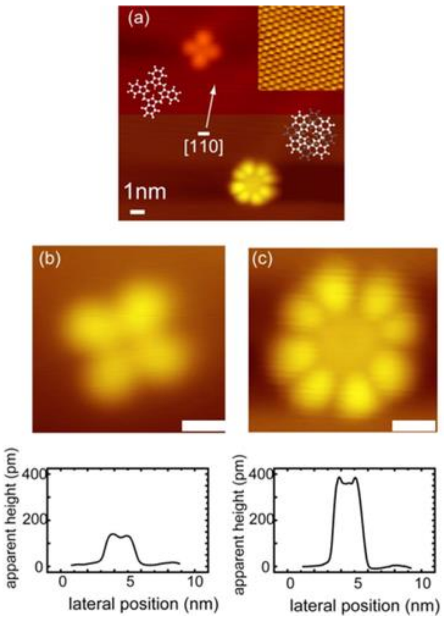
STM electronics allows to control the tip position such that tunneling current (thus tip-surface distance) is kept constant, while scanning a small area of the sample surface

movement is recorded, resulting in surface topography image.
In ideal conditions, individual atoms on the surface can be resolved

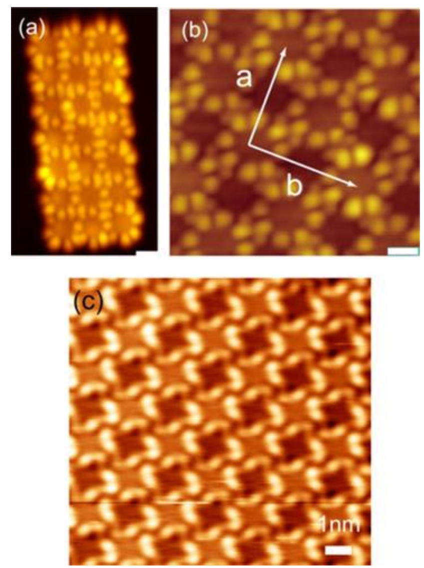
STM images shows the *geometric structure* of the surface, while depending on the electronic density of states of the sample, as well as on *tip-sample interaction*

STM Characterization

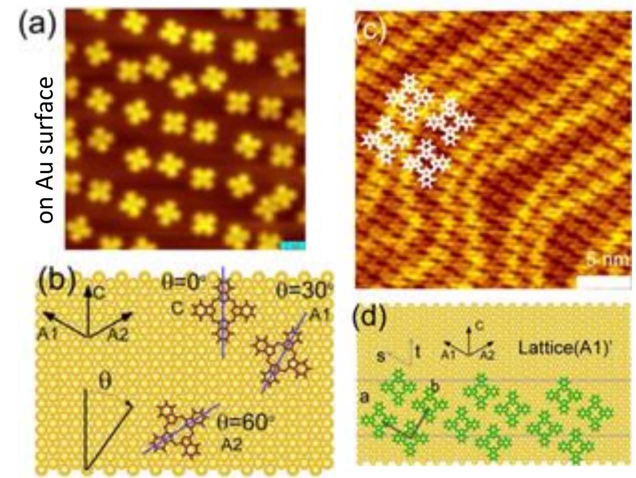
STM studies of single or small agglomerates of phthalocyaninato Tb(III) complexes



Single molecule $TbPc_2$ (bars 1nm)



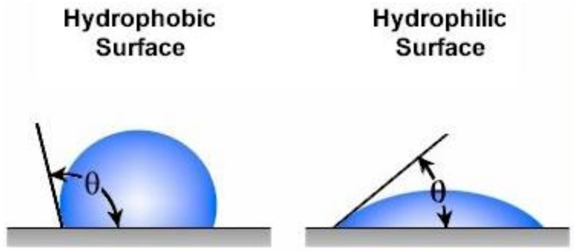
$TbPc_2$ film composed of 21 molecules



STM image of adsorbed H_2Pc molecules on Au surface

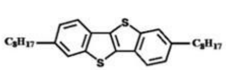
Chem. Rec. **16**, 987 (2016)

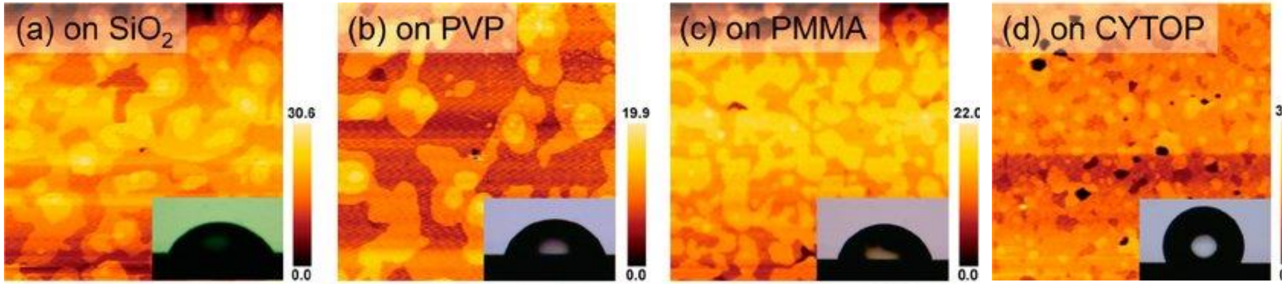
Surfaces Properties for Organic Materials



Contact angle, θ (theta), is a quantitative measure of **wetting** of a solid by a liquid. θ is defined as the angle formed by a liquid (*i.e.* water, solvents) at the 3-phase boundary where a liquid, gas and solid intersect

OSC deposition on different surfaces leads to overall quite different surface properties (*i.e.* height profile, roughness, hydrophobicity, ...)



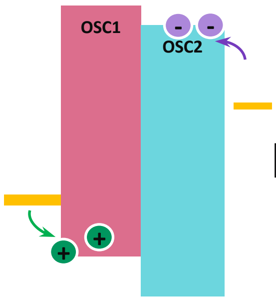


AFM images of C8-BTBT (30nm) on (a) SiO_2, (b) PVP, (c) PMMA and (d) CYTOP. Scan size is 10μm×10μm and lateral bar is in nanometers. Surface contact angle measurements are also shown in insets.

J. Phys. Chem. C **117**, 12337 (2013)

Interfaces in Organic Devices

for a charge moving into a device:
- **OSC/metal →** injection/charge extraction
- **OSC/OSC** interface
- other interface (*i.e.* **dielectric/OSC**)



the more interfaces in the device the more ***complicated it become for a charge to move/exit*** *from the device itself* (and all other processes in the devices - *light emission*)

OSC/metal interface
alignment of the OSC charge transporting states with metal E_F is crucial for device functionality

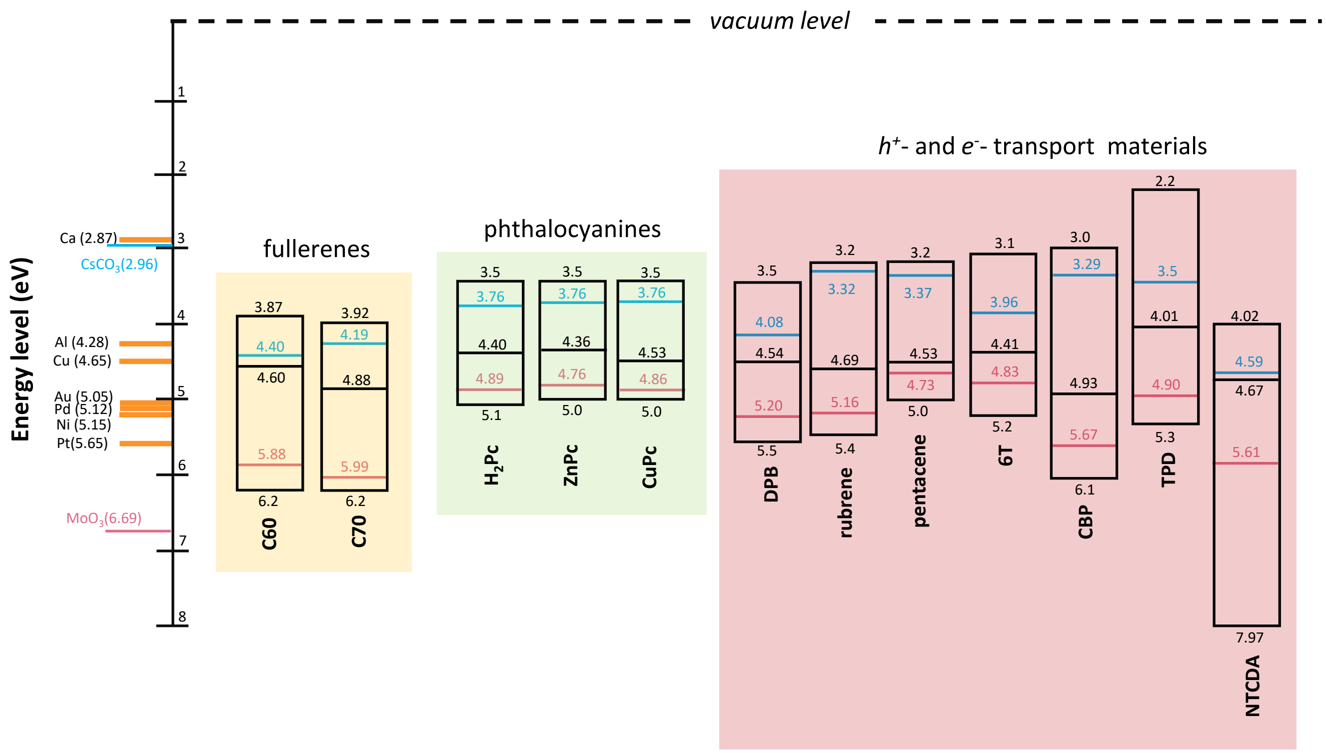
- surface energy & morphology
- trapping

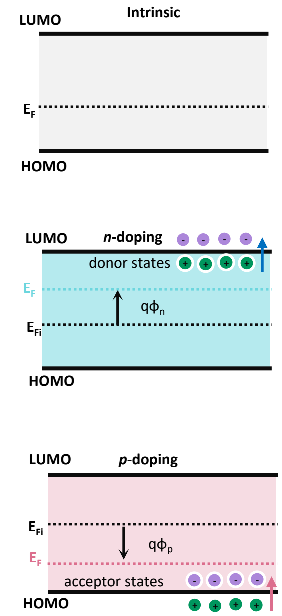
OSC/OSC interface
weak (van der Waals) interactions at OSS heterojunctions, where energy barrier can *enable/inhibit* charge transfer:
- surface energy & morphology
- trapping

dielectric/OSC interface
charge accumulation and transport (in OFET) occur at this interface:
- surface energy & morphology
- trapping
- surface dipole potential

Further reading: Nature Rev. Mat. **4**, 627 (2019)

Materials & Devices: Energy Consideration

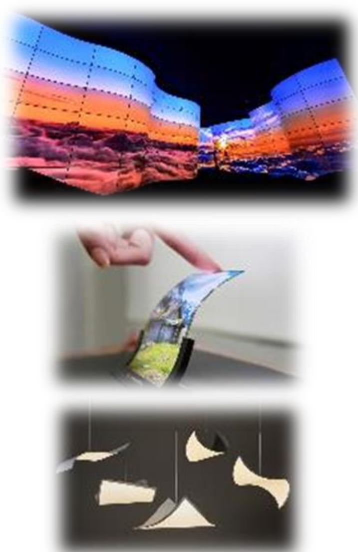




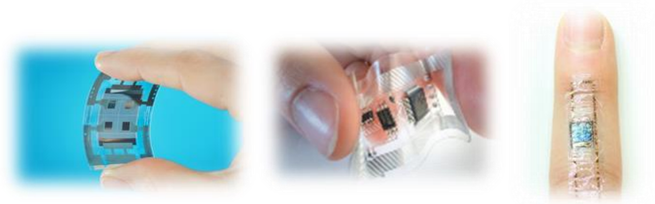
reproduced from https://www.mdpi.com/2079-9292/3/2/351/html

Organic Electronics Domains

Light Emitting Devices



Photodiode & (Bio)Sensors

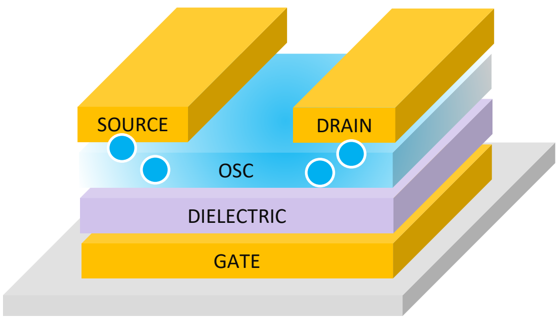


Wearable/Flexible Electronics

Solar Cells

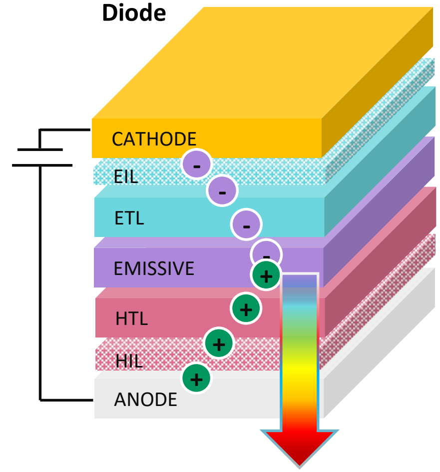
Key (Organic) Electronics Devices

Transistor



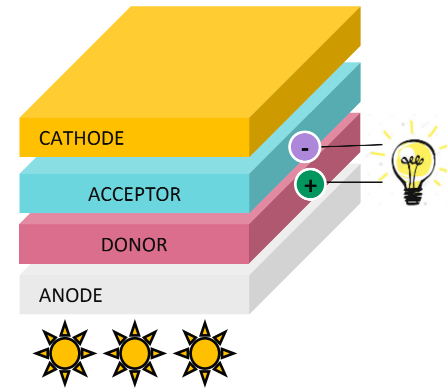
Field-Effect Transport (FET)
(*w/* Light Emission)

Diode



Current Injection &
Light Emission

Solar Cells



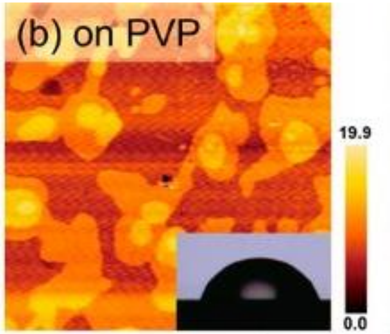
Light Absorption &
Charge Collection

- fundamental mechanism are similar to inorganic counterparts
- interfaces are crucial for device functioning

Summary

Today

Surface characterization of organic materials
Organic materials & devices: general considerations



Next

- **Organic Field-Effect Transistors**: structure, working principle
- Transistor **building block**
- **Applications** of Organic Field-Effect Transistors